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REMOTE SENSING INFORMATION SCIENCES RESEARCH GROUP

SANTA BARBARA INFORMATION SCIENCES RESEARCH GROUP

FINAL REPORT - YEAR 4

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ISRG

Remote Sensing Information Sciences Research Group

University of California, Santa Barbara

Final Report - Year 4

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Introduction
John E. Estes and Jeffrey L. Star

The Office of University Affairs of the National Aeronautics and Space Administration (NASA) signed a grant establishing a Remote Sensing Information Sciences Research Group (ISRG) at the University of California, Santa Barbara (UCSB). This document represents a report of work conducted under this grant (Grant # NASA NAGW-455) during the period May 1, 1986 to May 1, 1987.

ISRG research continues to focus on improving the type, quantity, and quality of information which can be derived from remotely sensed data. As we move into a new year of our research, we continue to focus on information science research issues of critical interest to NASA. In particular, we will focus on the needs of the remote sensing research and application science community which will be served by the Earth Observing System (EOS) and Space Station, including associated polar and co-orbiting platforms. Research conducted under this grant has been used to extend and expand existing remote sensing research activities at UCSB in the areas of georeferenced information systems, machine assisted information extraction from image data, artificial intelligence and both natural and cultural vegetation analysis and modeling.

As world population increases, there is an ever expanding need for systems and techniques capable of acquiring, integrating, and analyzing information concerning the extent, use of, and changes in the major components of the earth's surface. NASA is playing an important role in the establishment of a science of the biosphere through the development of systems such as EOS. EOS, which is scheduled to fly on polar platforms in the mid-1990 time frame, will have significant data acquisition capabilities. To achieve the full science and applications potential of such systems, however, requires that far-sighted fundamental research be directed towards the use of techniques and methodologies from which assessments may be made of both the current and changing status of the components of the biosphere, hydrosphere, lithosphere, and atmosphere.

The program of research, documented in this report, is being carried forward by personnel of the University of California, Santa Barbara. This report documents our past years accomplishments in what we consider to be a

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multiyear effort to prepare to take full advantage of the system's capabilities of the platforms and systems associated with Space Station Complex. Through this work, we have targeted fundamental research aimed at improving our basic understanding of the role of information systems technologies and artificial intelligence techniques in the integration, manipulation and analysis of remotely sensed data for global scale studies. This coordinated research program is possible at UCSB due to a unique combination of researchers with experience in all these areas.

Efforts during the early years of this grant focused on the integration of existing research activities at UCSB and the initiation and conduct of a number of research activities with a variety of NASA centers. We have also worked on background assessments of research and technology, as well as beginning steps towards implementation of a Pilot Land Data System (PLDS) for NASA Headquarters. We continue to be involved in PLDS development efforts, largely through the Science Steering Group. In addition, UCSB personnel have been involved with: the EOS Data Systems Panel; Space Station Data User Working Group; Space Station Operations Task Force; Science and Applications Information Systems Working Groups; Global Resources Information Systems; Earth Science and Applications Data System (ERDAS) Workshop and Committee; the United Nations Environment Programs Global Resources Information Database program; the Committee on Data Management and Computation (CODMAC) of the National Academy of Science; and, the National Academy of Science Mapping Sciences Committee.

In addition, during this past year we have received funds from NASA Code EI to supplement ISRG activities. These funds were proposed in September of 1985 to cover a range of tasks. We have also received a major grant from NASA Code EE/EI to study problems associated with Browse in the EOS era and have submitted a proposal to the Universities Space Research Association (USRA) to participate in a NASA funded telescience testbed effort.

The material which follows details ongoing work directly aided by this grant. Several of the projects used this funding as a catalyst to aid other NASA offices in the research, in the integration of remotely sensed and other data into an information sciences framework. The following

sections discuss the details of the projects dealing with:

* Studies Related to ISRG/Information Science Office
Research

* Artificial Intelligence and Geographic Information Systems,
KBGIS- II: A Knowledge-Based Geographic Information System

* Requirements and Principals for the Implementation and
Construction of Large Scale Geographic Information Systems

* The Regression Intersection Method of Adjusting Image Data for
Band Rationing

* Telescience Testbed: Rapid Prototyping for Multidisciplinary and
Distributed Earth Science Applications

* University Research Libraries Group, Geographic Information
System for Scholars

These projects are discussed in some detail in the following sections.
This Progress report concludes with a summary section outlining the coming
year's activities.

Research Activities for the Information Systems Office

John E. Estes and Jeffrey L. Star

In 1985, UCSB ISRG proposed studies to directly support the efforts of NASA's Information Systems Office, Code EI. Our proposal discussed a number discipline areas which continue to be relevant to Code EI, and we have been in close contact with Code EI staff to determine which of these task areas provide the greatest return to NASA and the Information Systems Office. In the following text, we describe the different task areas and the work accomplished in each area.

The UCSB Information Science Group suggested the following topics for special studies for Code EI:

1. The interaction between the Code EI data pilots and the proposed EOS data system, and impacts on the university earth science remote sensing community;

2. University workstation activities and requirements as they relate to NASA Center and NASA Land and Ocean Data Pilots;

3. University roles in the planning and development of the OSSA Science and Applications Information System;

4. The impact of the imposition of uniform NASA data standards on university research;

5. University roles in the development of a Global Resources Information System;

6. Artificial Intelligence and the Image Understanding Process; and,

7. A Workshop on University Information Systems Requirements.

A good deal of planning, research, and operational effort has occurred through the Pilot Land, Ocean and Climate Data Systems, and somewhat independently, on the Earth Observing Systems data system. Panels (with in

some cases overlapping memberships) have convened on a number of occasions.

However, until the initiation of the Earth Science and Applications Data System (ESADS) activity, there had been little examination of the interactions between pilots and the EOS data system, nor what such interactions may imply for the academic Earth Sciences Community involved in remote sensing research. Questions involve hardware, software, and communications compatibility issues. Links to NASA Centers and to other national (plus state, and local) as well as international data bases will also be involved. Universities will be an important part of the user community for the EOS and Pilot systems. However, what are the key issues involved in facilitating the use of data from these systems by university scientists? What needs to be accomplished to insure that this important segment of the university community can participate to the fullest extent in the research opportunities afforded by these systems?

NASA, through Code EI, Information Systems Office (ISO) has conducted studies over the past decade which have lead to the establishment of a number of pilot data systems. These pilot data systems are oriented towards the science driven data/information needs of users in defined disciplines under the NASA research umbrella. To date, pilot systems have been undertaken in the planetary, climate, oceans and land sciences areas.

The goal of these systems is to provide a variety of types of support for NASA and NASA related researchers. This support includes the maintenance of directories and catalogues, the formatting and preprocessing of data and the facilitation of communications between discipline scientists conducting NASA research.

NASA is also planning for Earth Observing Satellite System (EOS). EOS is designed to aid scientists in addressing the multidisciplinary earth science problems. The system must provide relevant information for detailed local studies, as well as for investigations aimed at an improved

understanding of global dynamics. Recognizing the importance of such a system to scientific understanding, the EOS Science and Mission Requirements Working Group recommended that NASA should develop the Earth Observing System as an information system mission.

University researchers will make up an important element of the user community for information from both the Data Pilots and EOS. Yet, in the studies conducted to date, little attention has been focused on either the specific needs or the generic problems involved in achieving optimum university participation in such systems. We propose to conduct such a study.

Specifically, we have examined the operation of current NASA pilot systems as they pertain to interactions with university researchers. A preliminary version of this material is presented in a following section of this report. The report discusses the similarities and differences in the various pilots. It also discusses how the pilots have been organized in support of their diverse user communities and the level of satisfaction on the part of both "users" and "operators" of the pilot systems.

Our work in this area is continuing. In the coming months and into next year we will broaden somewhat the scope of this activity to examine what features of these pilots support the EOS Data System Concept as outlined in the Reports of the EOS Data Panel. The study will also look into how these existing pilots might be more effectively linked to the broader NASA sponsored University Community. In addition, we will continue to support the NASA joint Code EE/EI Earth Science and Applications Data System effort. ESADS was conceived as a mechanism to bring the Earth Sciences and Information Systems communities closer together.

An ESADS workshop was held this spring in Easton, Maryland. At this workshop, current Code EI research in data systems was discussed along with Earth Science and Applications scientists data systems' needs. Out of this

workshop came a document detailing priority issues which the Earth Science and Applications felt needed to be addressed. The concepts developed at this workshop and the implementation of the recommendations made will be watched by the ESADS committee. The ESADS committee is made up of NASA, federal agency and university personnel. The committee is charged with reviewing Code EI's response to the ESADS recommendations. The ESADS committee is, at the present time, viewed as a long term activity. Both Drs. Estes and Star attended the ESADS workshop at Easton, where Dr. Estes chaired the panel on Directories, Catalogs and Browse. Dr. Estes also serves as a member of the ESADS committee.

Science and Applications Information System

Another area of increased interest is large scale information systems. The Science and Applications Information System planning effort is currently being conducted within NASA Code E. This system, as currently envisioned, is being planned to answer the science and applications information systems requirements of NASA and NASA associated researchers working under Code E funding. This wide ranging effort is critical for effective and efficient use of EOS and other advanced systems being developed for use in the Space Station time frame of the 1990's and beyond.

We proposed to provide a university perspective to the SAIS planning process. We feel this is an important area where study and interaction with the University community is required. This has included working closely with NASA Headquarters and center personnel who are actively involved in the planning process. Questions regarding links to universities, transfer of data, data archiving, value added services, and standards are all of critical concern. The role of existing pilots and university beta test sites also should be addressed. For example, should SAIS planning be scenario driven? Expandability, heterogeneous networks, and system evolution are all important concepts to the SAIS. As a result of our efforts in this area, Dr. Estes and Dr. Star work on SAIS activities through various SAIS panels with NASA and other university personnel. Indeed, a major SAIS working group meeting was held the week of February 9,

1987 at UCSB. At this meeting, a cross-section of NASA and NASA-sponsored scientists met to be brought up-to-date on the Space Station program, and to focus on refining the structure of an SAIS system.

We at the ISRG will continue to support SAIS activities through reviews of project plans and attendance at SAIS science and working group meetings. In addition, our activities in the development of an image processing test bed under contract to the Universities Space Research Association (USRA) will directly support our work, testing the SAIS concept for Telescience use of Space Station polar platforms in the EOS era.

Data Standards

Data standards have been discussed by many NASA and other federal agencies as well as science community committees for a considerable length of time. The imposition of standards implies that some change in operational procedures will be required to insure compatibility. What impact will changes in data structures or headers have on university research and operations? To some extent, this can be examined within the context of changes which have occurred in Landsat data formats. The problem here, however, is much broader and the issues and impacts upon the university community need to be addressed.

We have been working with Jet Propulsion Laboratory personnel on data standards for the earth science community. In this study, we are trying to determine both the advantages and potential disadvantages of establishing standards. The orientation of the study is to consider what minimum set of standards will improve and not impede universities' abilities to employ NASA acquired remote sensor information in an effective and efficient manner.

The study has examined one proposed data format family, based on a data description language. We have, working with JPL personnel, written

software for both the IBM PC/AT and the VAX under Unix, to test the efficiency as well as the logical structure of the proposed data standard. This part of the effort will continue at a lower level in the second half of the current contract year, as the standard and our software undergo review. Current practices and procedures for acquisition, processing, analysis, reporting, and storing of information will be reviewed. Areas where standards can be employed to improve this process will be discussed, including communication between sites and the development of geographic information systems. We will also discuss the role of standardized software interfaces. Emphasis will be placed on determining a minimum set of standard formatting and processing procedures which will provide the greatest benefit to the university community.

Global Resources Information System

In recent years, NASA has been moving towards conducting global scale studies with time durations on the order of decades. Study documents in the form of program plans have been developed for land-related global habitability studies and for global biology studies. In addition, the Space Station and its associated sensor platforms are being justified in part on the basis of long term research studies on topics of global significance and concern. The Earth Observing System (EOS) Science Steering Group document clearly points out the need for such studies. This same document also points out the need to consider EOS as an information system.

ISO, at the urging of congress, has been developing the concept of a Global Resources Information System (GRIS) for the past several years. These studies have been lead by researchers at the Jet Propulsion Laboratories. There is clearly a need for such systems. That need extends from the use of such data as might be contained in such a system in a policy making context, in a commercial context, and in a research and development context. While the two former uses (policy and commercial) are important, a case can be made that the research and development aspects of the data in such a system would be extremely significant. The question

asked then is, who will be the real beneficiaries of such a system? It is clear that among the top beneficiaries will be university researchers. As one of these, we have proposed a study of how universities can contribute to the Research Activities for the Information Systems Office development of a Global Resources Information System.

A strong case can be made that some of the greatest beneficiaries of a Global Resources Information System (GRIS) will be found in the university research community. Policy makers and federal agency personnel will make extensive use of these data, but it will be university researchers, doing advanced work in analysis and modeling, who stand to reap significant near-term benefits from the global harvest of data which can be provided by such a system. As such, it is important to understand the roles which can be played by universities in the development of a GRIS-type system and to address the issue of university participation in the development and operation of Global Scientific Information Systems.

As such, UCSB personnel have visited and will continue to work closely with personnel of the UNEP/GRID program in Geneva, Switzerland, as well as with personnel of the World Bank and NASA on Support for Global Science and Applications research. An outgrowth of this work was the placing of an intern at the World Bank this past year. Our student worked toward his Master's Degree, and was responsible for operating an image processing system at the World Bank Headquarters in Washington, D.C. Our student, Mr. Paul Lefebvre, participated in training of Bank employees as well as participating directly in the development of materials for Bank projects in developing nations. This was part of an effort at the World Bank, evaluating the utility of remotely sensed data, as well as developing some in-house experience with the information systems requirements. We have now negotiated another intern arrangement with the World Bank. Mr. Douglas Grice, another UCSB Master's degree candidate, is now at the World Bank. Bank personnel have expressed considerable interest in this program. We hope our efforts in this area will continue to be successful.

In addition, we at UCSB working with personnel from Code EE and the National Science and Technology Laboratory at Bay St. Louis, Mississippi, have proposed an effort to support the upgrading of computed facilities and the UNEP/GRID facility in Nairobi, Kenya. This proposal has been tabled at the present time owing to changes in user needs at UNEP/GRID Nairobi. We remain interested in and are actively pursuing improved insights into the institutions, techniques and methods currently available for the conduct of large scale and global science. We feel our activities in this area are progressing well. In addition, we feel work of this type must continue to examine ways to improve science and applications data linkages on the international level. This work is important if we are to move toward the goals laid out by the Earth Science Steering Committee in the Earth System Science Report.

Artificial Intelligence

Image analysis is a process which is integral to all remote sensing systems. Despite advances in computer-assisted image processing, the information extraction potential inherent in digital image processing lags behind the level of information extraction exhibited by manual image interpretation techniques. An examination of the processes involved in computer-assisted versus manual image interpretation reveals that computer assisted techniques rely largely on a single element, specifically tone or color, and a primitive form of texture; whereas manual interpretation techniques incorporate much higher level inputs (e.g., context).

Since concepts from the field of artificial intelligence (AI) have proven useful in applications similar to those found in the interpretation and analysis of remotely sensed images, UCSB has been conducting research for several years to identify specific research directions in which AI techniques can be applied to remote sensing with potential high returns. Much of this work has been driven by Prof. Terrence Smith, co-investigator on this grant. This leads us to initiate a low level study in which some of the fundamental research required in the development of a computer assisted interpretation system is conducted.

* Since the data inputs to an image interpretation system are by necessity varied and complex, a reasoning model must first be developed that incorporates the various data forms and models their interactions and preferred order of occurrence. This involves the integration and structuring of the knowledge of expert image interpreters, and the formation of information structures which allow efficient storage and access to the varied data forms. The data may be digital (image or other collateral data) or semantic in nature, and may concern either the applications area or background information concerning the region to be analyzed.

* In order to optimize the efficient search through a large and complex knowledge base, a system must have some way of prioritizing the processing instructions. One way to develop this prioritization is by conducting a case study of the computer assisted processing and analysis of land use/land cover classification studies, in order to develop reasonable a priori probabilities for the initial program. These a priori probabilities could then be incorporated into the decision model to indicate the preferred processing flow.

* Lisp is often cited as the language of choice in an AI program. However, in a digital image processing context, where simply an excess of input/output initiations can produce an increase in the cost of running an image processing program by an order of magnitude, Lisp may not be the most appropriate programming language. A study is needed that will examine the unique problems involved in the data structuring, data interaction and digital processing to determine which programming language would be optimal for that data or instructional module. The languages which would be examined for this study would include Lisp, Prolog, C and Fortran. It is anticipated that different modules would be optimally represented in different languages. This could be followed by a cost/benefit analysis to integrate the development and operational considerations involved in a computer-assisted analysis system in order to reveal the programming direction to task in the design of such a system.

This study will form the basis for a Master's thesis and we look forward to producing several reviewed journal articles in this area in the near future.

Conclusion

In conclusion, we believe that our work in this area represents a particularly efficient mechanism for the UCSB ISRG to support NASA's Codes EE and EI. With the decision on which technical and scientific tasks are most important remaining with Code EI staff, we are able to respond to changing needs and requirements at Headquarters on a timely and efficient basis. We feel that this relationship has been very beneficial, and look forward to the continuing opportunity of supplying a university perspective to Code EI.